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DMCII Geometric Quality Testing for CAP Control with Remote Sensing Programme – Initial Findings

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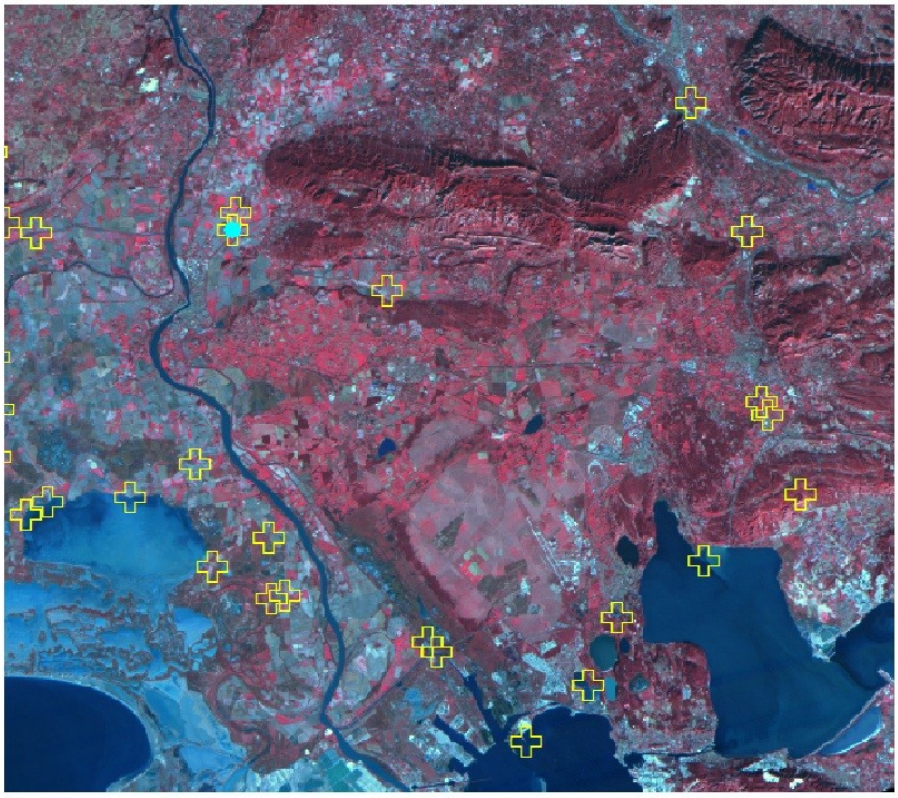

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1. Objective

This report summarizes the outcome of the geometric quality testing of the DMC2 images acquired over the JRC Maussane Terrestrial Test Site.

The objective of this study is twofold:

(1) to evaluate the planimetric accuracy of the orthorectified DMC2 imagery;

(2) to check if the orthorectified imagery of the DMC2 meet the Common Agricultural Policy (CAP) Control with Remote Sensing (CwRS) Programme technical requirements.

2. Data description

2.1. DMC2 satellite and image data

DMC International Imaging Ltd (DMCii) is a UK company which supplies satellite imagery products and services to a wide range of international customers. DMCii supplies both programmed and archived optical satellite imagery from the multi-satellite Disaster Monitoring Constellation (DMC).

The small satellites of the DMC provide daily revisit combined with an unmatched 640km imaging swath width for frequent broad area coverage. The DMC Consortium members work together through DMCii for commercial sales and for collaborative Earth observation campaigns.

DMCii provides imagery from satellites it owns and operates, UK-DMC and UK-DMC2 and also coordinates the commercial activity of the DMC satellite constellation. The DMC satellites are independently owned and operated by a cooperating consortium of organisations representing member nations: Centre National des Techniques Spatiales, Algeria; Beijing Landview Mapping Information Technology Ltd, China; National Space Research and Development Agency, Nigeria; Surrey Satellite Technology Ltd, United Kingdom; Deimos Imaging S.L., Spain

Two new British-built satellites satellites, UK-DMC2 and Deimos–1, launched onboard a Dnepr rocket from the Baikonur Cosmodrome in July 2009, supply the imagery of Ground Sample Distance to 22m whilst retaining the very wide 640 km swath that allow this imagery to be used for a wide range of applications. They are operating in green, red and near infrared spectra (source www.dmcii.com)

Orbital elements	
Orbit type	Near polar, Sun synchronous
Altitude	686 km
Inclination	98.2° (Sun synchronous)
Orbital period	98.4 min
Revisit rate	daily
Instruments	
Spectral band	MS1 (Green): 520nm - 600nm MS2 (Red): 630nm - 690nm MS3 (NIR): 760nm - 900nm
Spatial resolution	22 m (MS) at nadir
Radiometric resolution	11bits/pixel (storage 8bits/pixel)
Swath (footprint)	640 km x 900 km
Viewing angle	±30°

Table 1: DMC2 parameters (DMC Data Product Manual, 2010)

2.2. Processing Level Definitions of DMC2 image data product

DMCII currently offers the three data products:

- L0R - Raw Image data split into the 3 spectral bands (NIR, Red and Green) with Radiometric Calibration on all bands.
- L1R - All 3 Spectral channels combined into a band registered image using L0R data.
- L1T - L1R data orthorectified to sub-pixel accuracy (<25 metres RMS error) with respect to Landsat ETM+ reference data and the Hole-filled seamless SRTM DEM data V3 (90m, 2006) or 1km GLOBE DEM2 where the acquired image exceeds ±60° latitude.

The L1T products are projected to UTM / WGS84 by default. However, it is possible to orthorectify DMC images to any projection using any reference and DEM datasets as supplied by the customer.

All data products are delivered in the TIFF and GeoTIFF image formats.

2.3. Remark on the DMC2 orthorectification procedure and accuracy results

The L1R and L1T products are generated by an application called Keystone Workstation, developed by Swedish company, Spacemetric AB.

L1T DMC2-DEIMOS is an orthorectified product derived from the L1R product using manually collected GCPs from Landsat ETM+ data and SRTM DEM V31 data. The GCPs are collected manually by first finding a matching feature in both the DMC and reference images. The GCP is then placed on some part of that feature in both images to coarsely update the model. Finally, each GCP measurement is refined by using image overlay techniques to align other features surrounding the GCP. These adjustments are automatically fed back into the model and updated.

Once all the GCPs have been collected, the rigorous model adjustment is performed, which will then result in the x and y RMSE. These values must meet the DMC specifications. i.e. RMSE<17m for UK-DMC2 and Deimos-1 or RMSE<25m for AlSat-1, Beijing-1, NigeriaSat-1 and UK-DMC. If there are GCPs that are above the threshold then they will be removed from the model, replaced by another suitable GCP and the rigorous model adjustment is performed again.

These RMSE results, both in the x-direction and in the y-direction, are reported in the product metadata under the 'Quality Assessment' label.

It should be underlined that these geometric accuracy results are indeed a part of the orthoimage quality assurance process, and they are often referred to as internal quality control results. However they are not recommended to be used as the final orthoimage accuracy result within teh context of the Common Agriculture Policy (CAP) Control with Remote Sensing (CwRS). The EU standard for the orthoimagery to be used for the purpose of the CAP CwRS requires the assessment of the final orthoimage (Kapnias, 2008).

The RMS error calculated for Independent Control Points (i.e. points not included in the sensor model parameter estimation process, derived from an independent source of higher accuracy) in each dimension (either Easting or Northing) is used to describe the geometric characteristics of the orthoimage (product accuracy). This procedure is often referred as to external quality control (EQC).

2.4. Study area and DMC2 data for testing

The JRC Maussane Test site is located near to Mausanne-les-Alpilles in France. It has been used as test site by the European Commission Joint Research Centre since 1997. It comprises a time series of reference data (i.e. DEMs, imagery, and ground control) and presents a variety of agricultural conditions typical for the EU. The site contains a low mountain massif (elevation up to around 650m above sea level), mostly covered by forest, surrounded by low lying agricultural plains and a lot of

olive groves. A number of low density small urban settlements and a few limited water bodies are present over the site.

The MARS Unit was provided with two samples of the DMC2 image product level L1T thus geocorrected (sensor and lens distortions, curvature of the Earth, rotation of the Earth, spacecraft Attitude - removed) and already orthorectified (using manually collected GCPs from Landsat ETM+ data and SRTM DEM V31 data, and Keysone SIP/Ortho software). The products are cooregistered three spectral bands (0- NIR, 1- Red, 2- Green) with the nominal resolution of 22-meters resampled to pixel of the same size, provided in WGS 84 / UTM zone 31N projection and datum.

The image GeoTIFF files are accompanied by image support data, i.e. metadata file and RPC file, in the simple ASCII format.

The basic characteristics of our DMC2 images are as follows (Table 2):

Image ID number	DE001553s_L1T	U200011e_000000_015499_T_L1T_x01
Image product level	L1T	L1T
Acquisition Date	24 November 2009	20 December 2009
Sensor elevation angle at the scene centre (average off-nadir angle)	69 deg (19 deg)	83 deg (6 deg)
Pixel size GSD	22m	22 m
Tile size (img cropped to AOI)	175 km x 80 km	80 km x 80 km
Number of GCPs used for orthorectification process by Keystone	20	56
IQC – internal quality control results by DMC2 (sensor orientation phase)	8.5m (RMSEx) 5.4m (RMSEy)	15.3m (RMSEx) 14.9m (RMSEy)

Table 2: Basic metadata of the DMC2 sample images (according to image provider metadata file)

2.5. Validation Data

The points with known position that were not used during the used during the geometric correction model phase served as the validation sets[1] in order to evaluate planimetric error of the test orthoimage data.

Due to the lack of the GPS-based independent check points (ICPs) for such image size and resolution, I used the following two of the most stable HR sensors, as reference data:

- SPOT 5 supermode PANchromatic orthoimage of max RMSE of 5m and pixel size of 2.5m;
- LANDSAT 7 ETM+ Pan-sharpened Ortho bands composition of average relative accuracy of 30m RMS or better, and pixel size of 14.25m.

Features in the L1T DMC2-DEIMOS orthoimages that were also depicted on SPOT and LANDSAT were chosen as ICPs. A total of 41 ICP were established, but differences in image sizes and resolution prevented the use of all ICP in every image. Most ICPs were road intersections where the roads joined at angles of 60deg or more; however, the rural landscape and efforts to ensure that ICPs were evenly dispersed throughout the images required the use of oblique road intersections or alternative features (e.g. sea piers).

[1] also referred as to independent control points (ICPs)

3. Methodology

The EU standard for the orthoimagery to be used for the purpose of the Common Agriculture Policy (CAP) Control with Remote Sensing (CwRS) requires the quality assessment of the final orthoimage (Kapnias, 2008).

The RMS error calculated for Independent Control Points (i.e. points not included in the sensor model parameter estimation process, derived from an independent source of higher accuracy) in each dimension (either Easting or Northing) is used to describe the geometric characteristics of the orthoimage (product accuracy). This procedure is often referred as to external quality control (EQC).

We were provided with two samples of the L1T DMC2-DEIMOS orthorectified product derived from the L1R product using GCPs collected from Landsat ETM+ data and SRTM DEM V31 data using Keystone Spacemetric software. Therefore our workflow encompassed the external quality control (EQC) of these final products, also referred as to absolute accuracy check or validation phase.

Due to the lack of the GPS-based independent check points for such image size and resolution, the following two of the most stable HR sensors, SPOT 5 Supermode and LANDSAT 7 ETM+ were used as reference data:

- SPOT 5 supermode PANchromatic orthoimage of max RMSE of 5m and pixel size of 2.5m;
- LANDSAT 7 ETM+ Pan-sharpened Ortho bands composition of average relative accuracy of 30m RMS or better, and pixel size of 14.25m.

Since the absolute positions (e.g. DGPS measurement) of these check points are not known, the validation results can be interpreted as relative values to the reference orthoimages, i.e. SPOT5 Supermode or LANDSAT 7 ETM+ orthoimage accuracy. The geometric characteristics of the SPOT5 Supermode image, and in particular its spatial resolution, are one significant digit better that the being studied DMC2, therefore (only within this context) the ICPs coordinates measured on SPOT5 Supermode orthoimage can be treated as the absolute coordinates.

4. Results and Discussion

4.1. Outcome of the external quality control using SPOT5 SM as reference data

For 175kmx80km tile, sensor elevation angle of 69deg (off-nadir 19deg), acquired on 24 November 2009 - the RMSE_X=16m, RMSE_Y=22m, or 20m and 25m if DEIMOS-1 point identification error included; For 80kmx80km tile, sensor elevation angle of 83deg (off-nadir 6deg), acquired on 20 Dec 2009 the RMSE_X=28m, RMSE_Y=20m, or 30m and 23m if DEIMOS-1 point identification error included.

Image ID number	DE001553s_L1T	U200011e_000000_015499_T_L1T_x01
Image product level	L1T	L1T
Acquisition Date	24 November 2009	20 December 2009
Sensor elevation angle at the scene centre (average off-nadir angle)	69 deg (19 deg)	83 deg (6 deg)
Number of ICPs used for validation (EQC) process	39	35
EQC – external quality control results (by JRC)	16m (RMSEx) 22m (RMSEy)	28m (RMSEx) 20m (RMSEy)
EQC – external quality control results (by JRC) if DEIMOS-1 point identification error included	20m (RMSEx) 25m (RMSEy)	30m (RMSEx) 23m (RMSEy)
IQC – internal quality control results by DMC2 (sensor orientation phase)	8.5m (RMSEx) 5.4m (RMSEy)	15.3m (RMSEx) 14.9m (RMSEy)

Table 3: Summary of the external quality control using SPOT5 SM as reference data

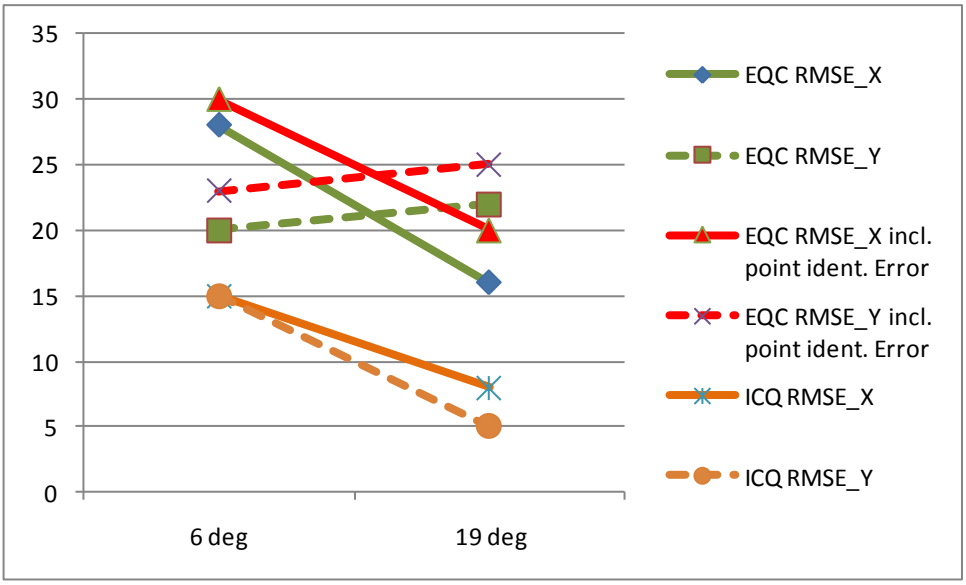

Figure 1: 1-D RMSE [m] for 35 ICPs measured on the DMC2 orthoimage (level 1T) as a function of the overall off-nadir angle after the single scene correction applying the Keystone SIP/Ortho rigorous model based on the GCPs collected from Landsat ETM+ data and SRTM DEM V31 data with 16m vertical accuracy. Additionally, the IQC results obtained during sensor orientation phase are presented for comparison (in orange).

These geometric quality results are very promising, however, it should be borne in mind that:

- The tested DMC2 samples are very limited. Further testing is required, especially for diverse terrains and images characterised by high satellite inclination angle;

The one-dimensional RMS error based on the manual measurement of 35 (or 39) well-distributed Independent Check Points (ICPs):

- is sensitive to the off-nadir angle;
- is of questionable convergency with decreasing off-nadir angle. This observation is also noticeable from the results obtained by DMC Company during sensor orientation phase (IQC – internal Quality control).

4.2. Outcome of the external quality control using LANDSAT 7 ETM+ as reference data

For 175kmx80km tile, sensor elevation angle of 69deg (off-nadir 19deg), acquired on 24 November 2009 - the RMSE_X=29m, RMSE_Y=18m, or 42m and 35m if reference LANDSAT accuracy influence is included; For 80kmx80km tile, sensor elevation angle of 83deg (off-nadir 6deg), acquired on 20 Dec 2009 the RMSE_X=17m, RMSE_Y=25m, or 34m and 39m if reference LANDSAT accuracy influence is included.

Image ID number	DE001553s_L1T	U200011e_000000_015499_T_L1T_x01
Image product level	L1T	L1T
Acquisition Date	24 November 2009	20 December 2009
Sensor elevation angle at the scene centre (average off-nadir angle)	69 deg (19 deg)	83 deg (6 deg)
Number of ICPs used for validation (EQC) process	39	35
EQC – external quality control results (by JRC) Relative 1-D RMSE	29m (RMSEx) 18m (RMSEy)	17m (RMSEx) 25m (RMSEy)
EQC – external quality control results (by JRC) if reference LANDSAT accuracy included Absolute 1-D RMSE	42m (RMSEx) 35m (RMSEy)	34m (RMSEx) 39m (RMSEy)

Table 4: Summary of the external quality control using LANDSAT7 ETM+ as reference data

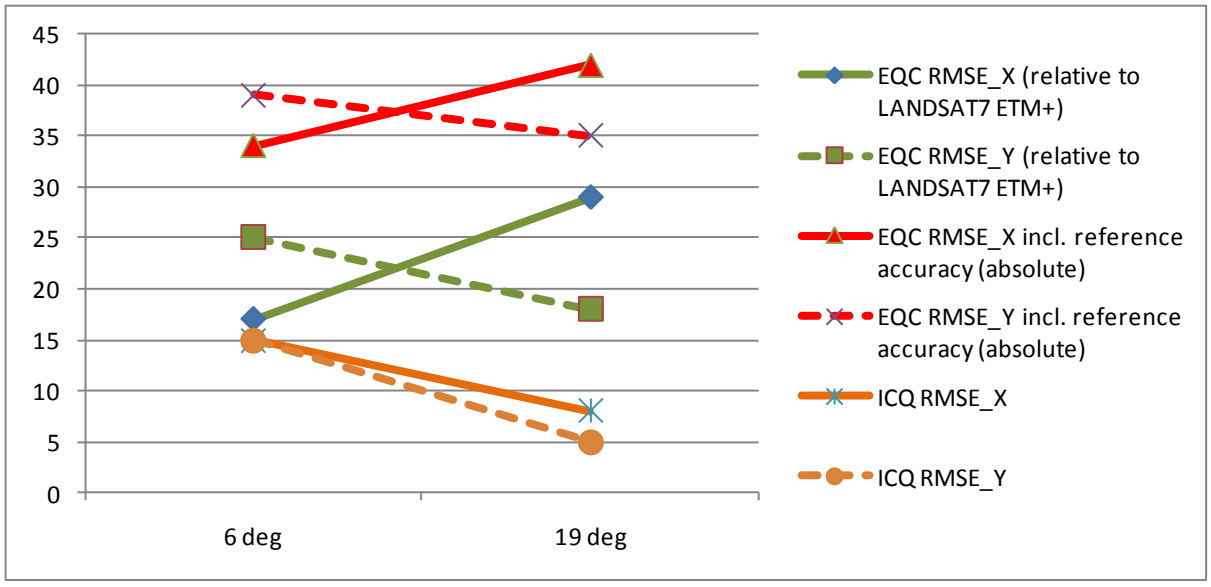

Figure 2: The relative (to the reference LANDSAT7 ETM+) and absolute 1-D RMSE on 35 ICPs [m] measured on the DMC2 orthoimage (level 1T) as a function of the overall off-nadir angle after the single scene correction applying the Keystone SIP/Ortho rigorous model based on the GCPs collected from Landsat ETM+ data and SRTM DEM V31 data with 16m vertical accuracy. Additionally, the IQC results obtained during sensor orientation phase are presented for comparison (in orange).

5. Summary of Key Issues

This report presents the geometric quality results recorded for the two samples of the DMC2 orthorectified products (processing level 1T) acquired over the JRC Maussane Test Site.

The key issues identified during the geometric quality testing based on the limited DMC2 sample images that were made available to us are summarised below:

1. The one-dimensional RMS error based on the manual measurement of 35 (or 39) well-distributed Independent Check Points (ICPs) on the DMC2 L1T ortho product after single scene correction applying the Keystone SIP/Ortho rigorous model based on the large group[2] of GCPs collected from Landsat ETM+ data and SRTM DEM V31 data is:

- sensitive to the overall off-nadir angle;

- of questionable convergency with decreasing off-nadir angle.

This observation is also noticeable from the results obtained by DMC Company during sensor orientation phase (IQC – internal Quality Control).

2. The average 1-D RMSE for the above mentioned product are 22m and 21m of Easting and Northing direction respectively (i.e. about 1 pixel accuracy), or 25m and 24m if point identification error is included.

These values are valid if orthorectified SPOT5 Sumermode is used as reference data. If, instead, the LANDSAT7 ETM+ orthoimage is used as a source of the independent check points then the average relative (to the reference data) 1-D RMSE are 23m and 22m of Easting and Northing direction respectively, or 38m and 37m if 39m if reference LANDSAT accuracy influence is included.

3. These geometric quality results are very promising, however, it should be borne in mind that the tested DMC2 samples are very limited (i.e. two samples). Further testing is required, especially for diverse terrains and images characterised by high satellite inclination angle.

[2] At least 20 well-distributed ground control points (GCPs)

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Abstract
This report presents the geometric quality results recorded for the two samples of the DMC2 orthorectified products (processing level 1T) acquired over the JRC Maussane Test Site. It was shown that the average 1-D RMSE for the DMC2 L1T ortho product are 22m and 21m of Easting and Northing direction respectively (i.e. about 1 pixel accuracy), or 25m and 24m if point identification error is included. These values are valid if orthorectified SPOT5 Sumermode is used as reference data. These geometric quality results are very promising, however, it should be borne in mind that the tested DMC2 samples are very limited (i.e. two samples). Further testing is required, especially for diverse terrains and images characterised by high satellite inclination angle.

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